NCP1200

a compact switching power supply

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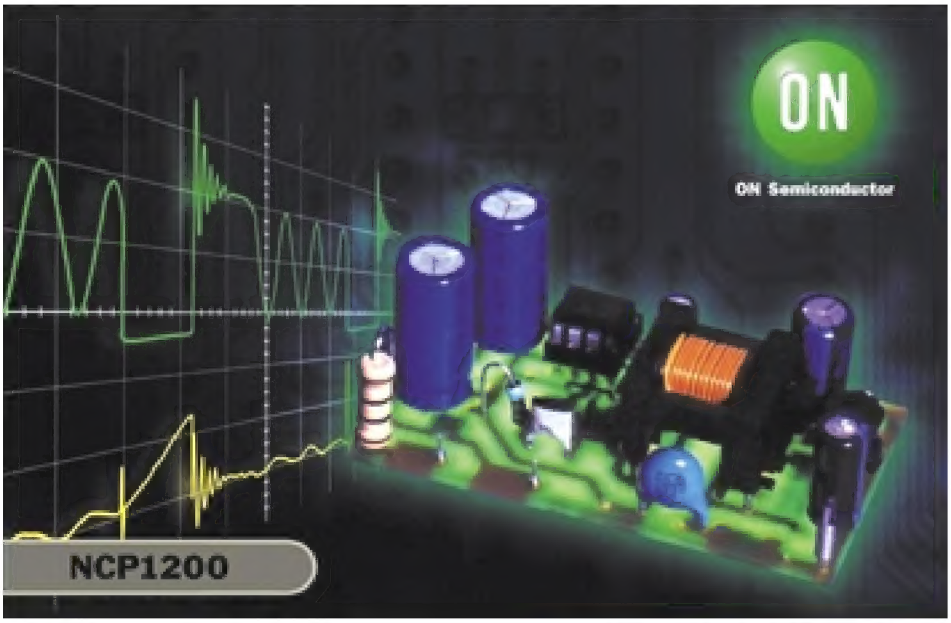
In designing a product that is powered from the mains, there are various factors that ultimately determine the choice of power supply. Increasingly more manufacturers are choosing a switching power supply, in part because of its light weight and high degree of flexibility.



Switching power supplies are often designed to have a 'universal' input, such that they can be directly connected to any desired input voltage (normally an ac voltage between 90 and 260 V). With a traditional solution using a transformer, different taps on the transformer would have to be selected to handle this range of input voltages. However, the less experienced among us are often put off by the idea of a regulated power supply, since it suggests complex circuitry that can generate quite a lot of smoke under the right circumstances!

Fortunately, semiconductor manufacturers regularly introduce new chips that make it easy for most power supply designers to master the technology. ON Semiconductor have made a significant advance in this area with the NCP1200, which has the advantage that most of the functions are integrated into a single chip, while at the same time the designer is given a certain degree of freedom (in choosing the MOSFET and controlling its conductance, for instance). This article describes how this new chip functions, based on the example of the construction of a complete 12 V / 10 W mains power supply with very low quiescent current.

A whole pack of innovations in an 8-pin package

First let's have a brief look at the new features:

- **No need for an auxiliary winding.** ON Semiconductor's high voltage technology (Very High Voltage Integrated Circuit, or VHVIC) allows the power supply to be fed from a power source connected to the mains network. The dc voltage from this source may be as high as 400 V. Only a VHVIC chip can handle such voltages. This technique frees us from the need for an extra transformer winding and associated components.
- **Short-circuit protection.** The NCP1200 is a current-mode regulator with a fixed switching frequency (40, 60 or 100 kHz). During normal operation, the IC continuously monitors the voltage on the FB (feedback) pin. If this voltage exceeds a threshold value for a certain predefined interval, the protection circuitry of the NCP1200 is activated. It remains activated as long as the fault is present, with only brief pulse bursts being delivered in order to limit the average power provided by the supply. This is referred to as 'burst mode' operation. The power supply switches back to the normal operating mode as soon as the fault is no longer present.

- **Low quiescent current**. The International Energy Agency (IEA) regularly prescribes new standards with regards to the standby power consumption of power supplies that are permanently connected to the mains. This includes devices such as chargers for cordless telephones, mains adapters for CD players and video games, television decoders and the like. The idea is to limit the standby power consumption as soon as the power supply no longer provides any power – for example, once the battery of a cordless telephone has been fully charged. Thanks to its 'cycle skipping' technology, in the standby mode the NCP1200 consumes less than 500 mW in the case of a 10W mains power supply (such as that described in this article).
- **No irritating whining**. The manner in which competing devices employ cycle skipping usually results in irritating noises, since the skipping rate (which falls in the audible frequency range) is accompanied by large peak currents. However, in the design of an inexpensive product, the price of a transformer that is quiet and insensitive to these audio-frequency voltages naturally weighs fairly heavy the overall budget. The NCP1200 solves this problem in an elegant manner by performing cycle skipping using only small peak currents. This technique guarantees noise-free operation in the standby mode. Mechanical noises from the transformer are thus held to a minimum. If there is still audible noise, the cycle skipping current level can be adjusted by modifying the voltage on pin 1 (ADJ).
- **An external transistor**. Single-chip solutions are deceptively attractive because they require so few components. However, an on-chip MOSFET transistor will immediately break down if the reverse induction of the transformer pulls the drain below V_{DSS}, with the result that the chip immediately gives up the ghost. Since the NCP1200 drives an external MOSFET, the designer can chose a type that can withstand occasional overloads, and in some cases can thus do without separate peak current limiting circuitry.
  In addition, a series resistor can also be included if you want to slow down MOSFET switch-on.
- **Spice models**. In order to accelerate the development of systems based on the NCP1200, ON Semiconductor offer two Spice models, depending on the desired type of analysis. The normal (averaged) model represents a small-signal current-mode flyback converter and allows a Bode chart to be produced in the blink of an eye. There is also a transient model in which all of the characteristics of the NCP1200 are represented, such as propagation time and current consumption. After the values have been entered into the simulation program, a simulation can be started and graphs appear on the screen to verify the correctness of the designer's calculations. Ready-to-use simulation platforms are available for Intusoft IsSpice4, Cadence Pspice and Spectrum Software Micro-Cap. The files can be downloaded from www.onsemi.com.

Dynamic power supply regulation

Traditional switching power supplies, such as those built around a UC384X, require a minimum load in order to start up. This role is usually assigned to a resistor (start-up resistor) connected directly to the high voltage line that draws several hundred microampères as soon as power is switched on to the equipment. After several cycles of current have been supplied, an auxiliary winding takes over from this resistor to continuously supply power to the regulator. In spite of the attractiveness of this idea, it has two major disadvantages:

1. When the auxiliary winding is powering the regulator, the start-up resistor still remains connected and wastes energy. This makes it difficult to comply with the IEA rules.
2. In battery charging applications, it can happen that a fully discharged battery has a voltage of nearly zero. In such a situation, the auxiliary voltage that is connected to the output in flyback mode disappears. The regulator receives too little power and can no longer do its job.

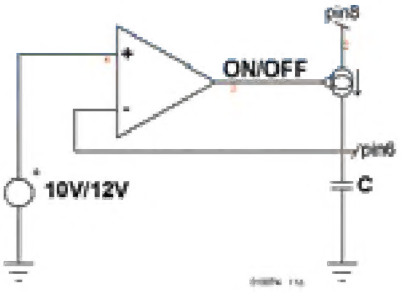


Figure 1a. Working principle of a dynamically regulated current source that provides a constant current to the IC.

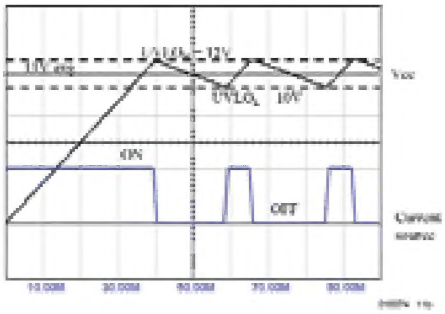


Figure 1b. The current source supplies 4 mA; V_{CC} varies between 10 and 12 V.

In order to permanently eliminate these disadvantages, the NCP1200 uses a dynamic current source that draws power from the high voltage line. The biggest difference between this and a startup resistor lies in the possibility of disabling or re-enabling this current source according to the needs of the regulator. Since the regular draws only a small current (around 1.2 mA), the amount of power that is wasted remains within reasonable limits and the IEA requirement can be easily satisfied. **Figures 1a** and **1b** illustrate the operation of this in detail. As can be seen from Figure 1a, the current source does not just supply power to the regulator circuit; it also charges capacitor C. Due to the design of this circuit, the current source regulates itself and continues to supply 4-mA pulses to the NCP1200 with a variable period, independent of the voltage level on the high voltage line (30–400 V_{DC}). The degree to which the IC contributes to the total power is given by the quantity $V_{line} \times I_{pin8}$.

The power consumption of the NCP1200 itself is governed by its internal structure (clock, comparators, opamps etc.). Another determining factor is the MOSFET connected to

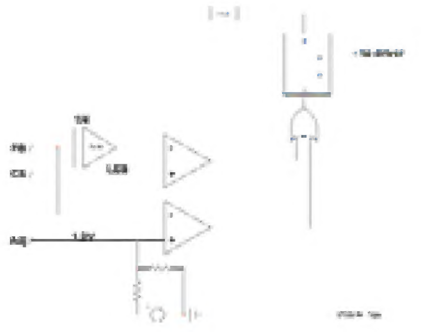


Figure 2a. The FB pin is continuously monitored by a comparator.

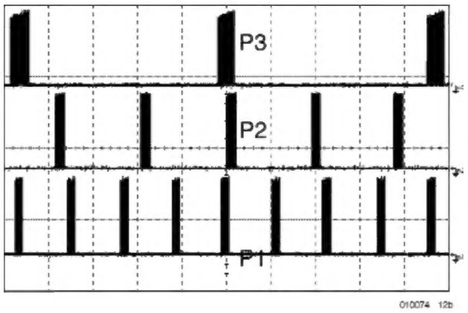


Figure 2b. Three different power levels in burst mode (P3<P2<P1).

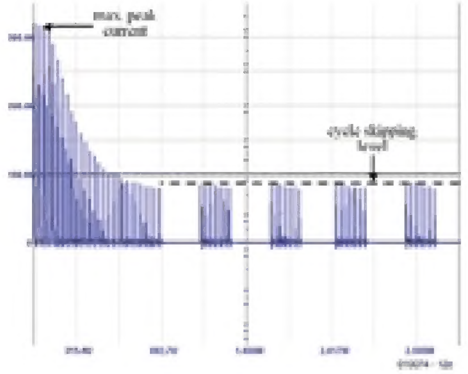


Figure 2c. Cycle skipping occurs only at low peak current levels.

the output. For example, if a 600-V MOSFET from ON Semiconductor is selected, such as the MTD1N60E, the total drive (total gate charge) is 11 nC. With a 40-kHz version of the NCP1200, this results in an average drive current of 0.5 F_{SW} Q_g = 250 µA, leaving aside considerations of drive efficiency. The variables in this formula are:

F_{SW} = maximum switching frequency (Hz),
Q_g = MOSFET gate charge (Coulomb).

The sum of this current and the normal consumption of the circuit amounts to around 1 mA. The total dissipation is thus approximately (330 V × 1 mA) = 330 mW.

Low standby consumption without objectionable noises

The NCP1200 works with a supply architecture that is referred to as 'current-mode'. The operating principle of this mode is that the peak current I_p flowing through the primary winding (L_p) of a transformer is continuously adjusted to achieve regulation. In the case of a flyback converter, the regulator attempts to satisfy the following relationship:

$$P_{in} = 0.5\ L_p\ I_p^2\ F_{sw}$$

It does this by modulating I_p, since L_p and the switching frequency F_{sw} are fixed. I_p is measured by means of a shunt resistor placed in series with the power MOSFET. The voltage so obtained is applied to the Current Sense (CS) pin of the NCP1200. This voltage is then compared with the voltage on the FB pin, which is internally divided by a factor of 4 (see **Figure 2a**).

FB is an electrical representation of the signal on the secondary winding, as transferred via an isolator (often an optocoupler). If the amount of power drawn by the load increases, the level on FB increases (up to 4 V), which results in a higher peak current in the primary winding. By contrast, a low voltage on FB is evidence of low output power. In all cases, the regulator adjusts itself to satisfy the previously given relationship.

If the load on the output is removed, the regulator continues to operate at a very modest level, but still at the same frequency (for example, 40 kHz). However, each cycle for which the MOSFET conducts increases the standby power. The NCP1200 attempts to prevent this as much as possible. One of the simple means to reduce the standby power is to skip cycles when the output power decreases.

The NCP1200 thus operates at a fixed frequency (with normal loading), and in addition it can automatically change over to cycle skipping (omitting cycles) when the output power is low. All that is needed to utilise this technique is a simple comparator, as is clearly illustrated in Figure 2a. As soon as the voltage on the FB pin falls below 1.4 V, a control element in the IC starts to suppress output pulses. The output pulses are thus modulated with respect to their number and repetition rate ('controlled burst' operation).

Figure 2b shows oscillograms of the NCP1200 output at various power levels. The most significant problem with systems that employ cycle skipping comes from the bundles of 40-kHz pulses, whose repetition rate can lie in the audible frequency range. A transformer is a mechanical element and can give rise to a resonance in the vicinity of this repetition rate. Such a resonance produces a highly irritating whistling noise, whose intensity depends on the peak current through the primary winding. Fortunately, the NCP1200 skips cycles only when delivering very little power. In this situation, the output has to supply only a small current, so there is no resulting noise generation in the transformer. If a given transformer nonetheless generates objectionable noise, the current level at which cycle skipping takes place can be adjusted by connecting pin 1 of the IC to a voltage divider attached to V_{CC} and GND.

A 10-watt power supply

The NCP1200 can be used to build regulated power supplies with capacities ranging from a few milliwatts to 30 W. The project described here shows how the regulator can be used in a mains power supply with a universal input and a power of around 10 W.

Figure 3 shows the schematic diagram of the circuit. As has already been explained, pin 1 of the IC is connected directly to the high voltage line in order to supply power to the IC. The transformer is a very simple type, with a primary winding and a secondary winding but without the usual auxiliary winding. In order to avoid any sort of arcing between the pins, pin 7 is left open to assure secure operation, regardless of the environment in which the circuit is used.

The MOSFET receives its drive sig-

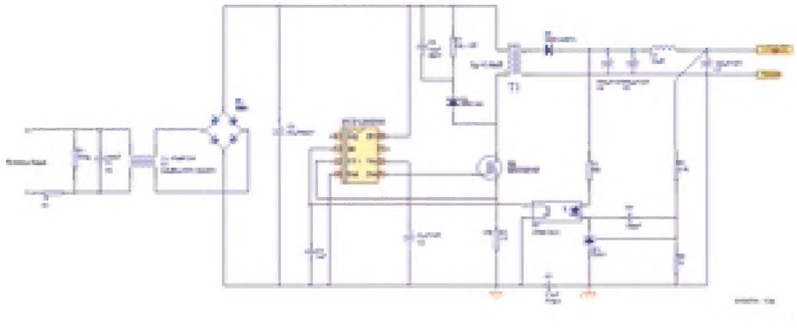


Figure 3. This schematic diagram clearly shows how easy it is to use the NCP1200.

nal from pin 5 with no intermediate resistor; the output stage already has an asymmetric structure that naturally curbs the transition to the conductive state. A TL431 in combination with an optocoupler provides the feedback. The latter device pulls pin 2 (FB) towards ground when the power demand at the output drops. If the voltage on this pin falls below 1.4 V (the default voltage on this pin), the pulses on the output stop and the regulator begins to skip cycles. If the FB pin is constantly held at ground level by a bipolar transistor, the NCP1200 is fully disabled and passes only the standby portion of the power. Finally, there is provision for peak current protection, since an excessively high voltage on the drain of the MOSFET could destroy the MOSFET.

The performance figures of the circuit are listed below. They provide evidence of both outstanding efficiency and low standby power (less than 480 mW with a mains voltage of 250 V_{ac}).

V_{inDC}	P_{out} [W]	P_{in}[W]	μ[%]
126	0	0.245	-
126	10.5	12.6	83.3
356	0	0.462	
356	10.5	13.17	79.7

The circuit is constructed using fully standard components. A ready-made transformer is available for this 10-W version.

In conclusion, we can state that the NCP1200 takes an approach that is different from that used by all other commercially available types of regulator ICs. As a regulator, it forms an extremely compact solution that leaves the user free in the choice of MOSFET and the peak current that flows through it. From an EMC perspective, the fact that the drive to the MOSFET can be precisely adjusted can certainly be considered to be an advantage. Finally, the availability of Spice models provides a considerable time savings in the design phase.

Extensive documentation (technical data, application notes etc.) is available on the ON Semiconductor website (www.onsemi.com) under the heading 'NCP1200'.

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